A multi variables statistical description of clouds over tropical ocean using daytime A-train high spatial resolution observations to assess cloud processes parameterization in climate model

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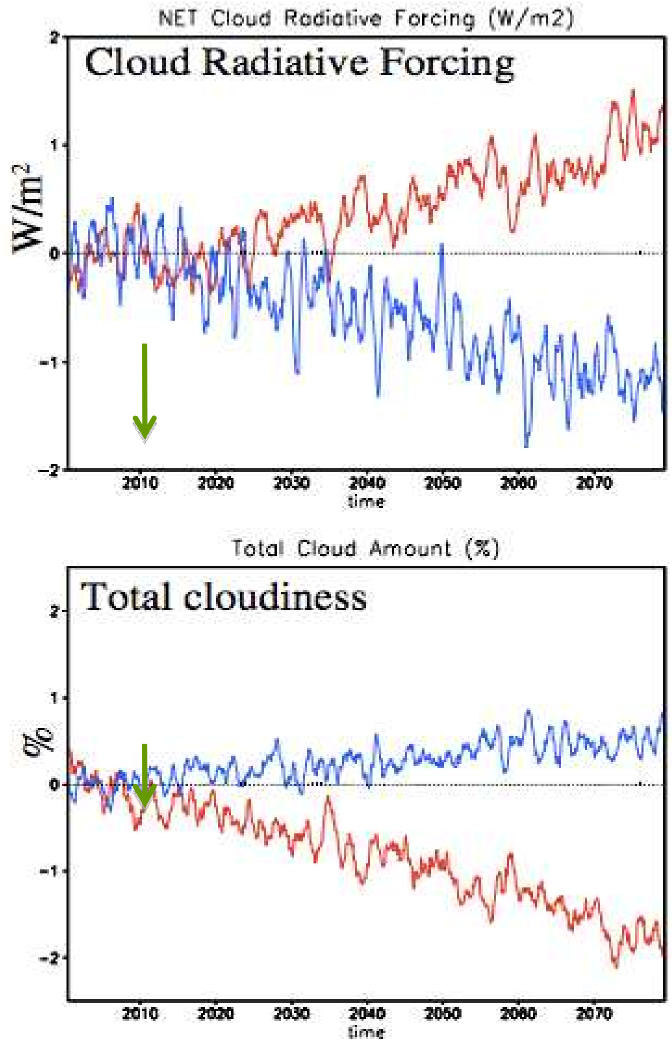
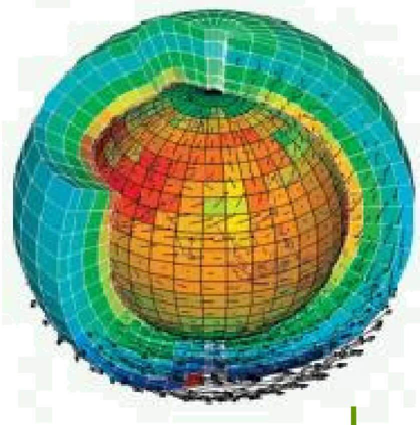
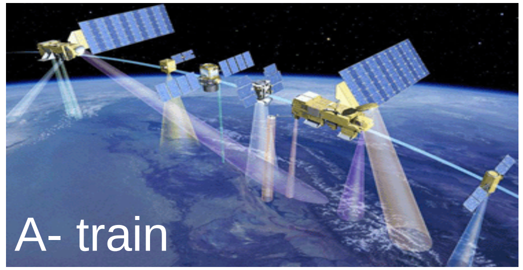
Background (1)

Scientific Question



Method





Simulators COSP

Specific data processing

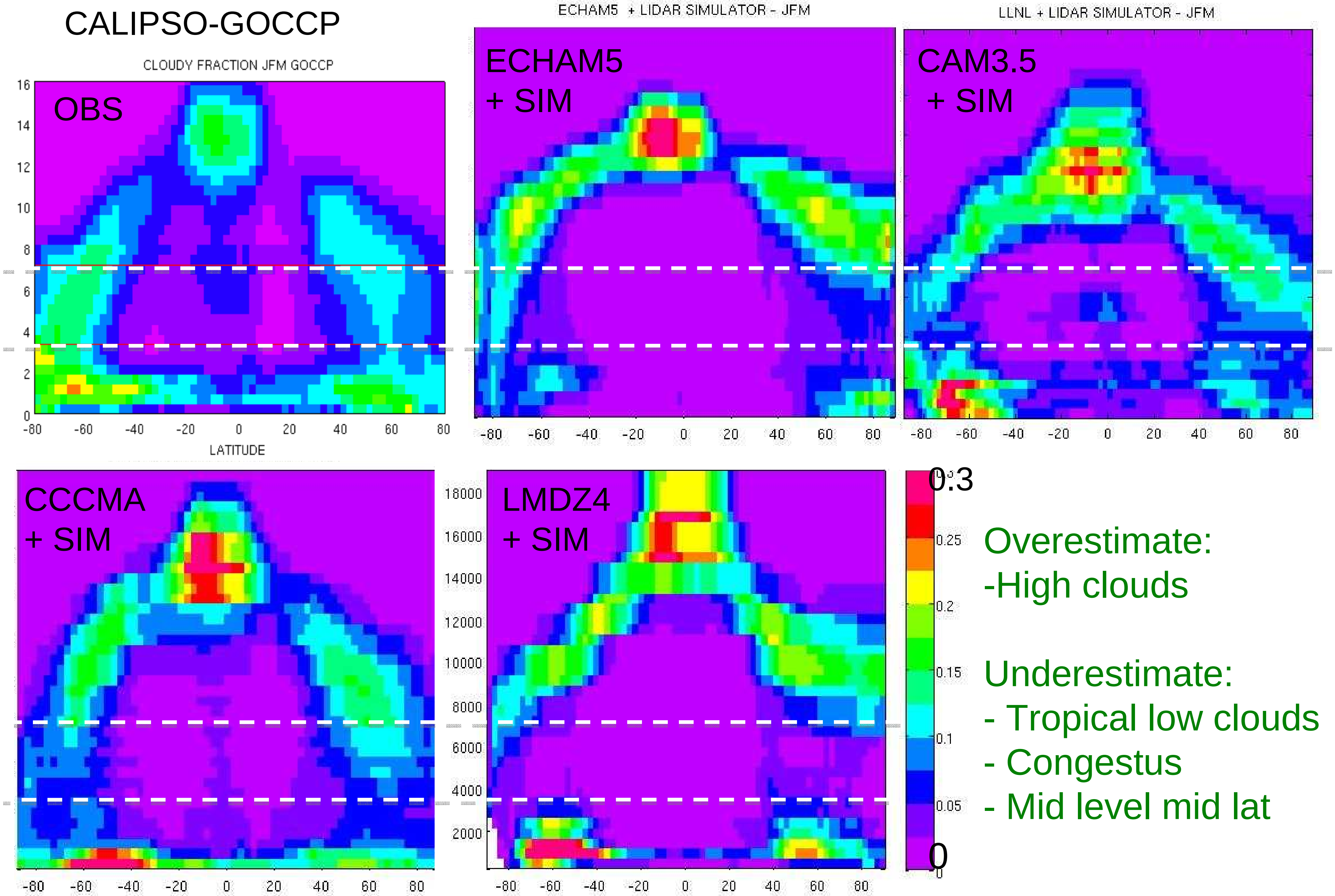
Simulated datasets

Dedicated datasets

evaluation

Reducing this uncertainty: a thorough evaluation of cloud description in climate models

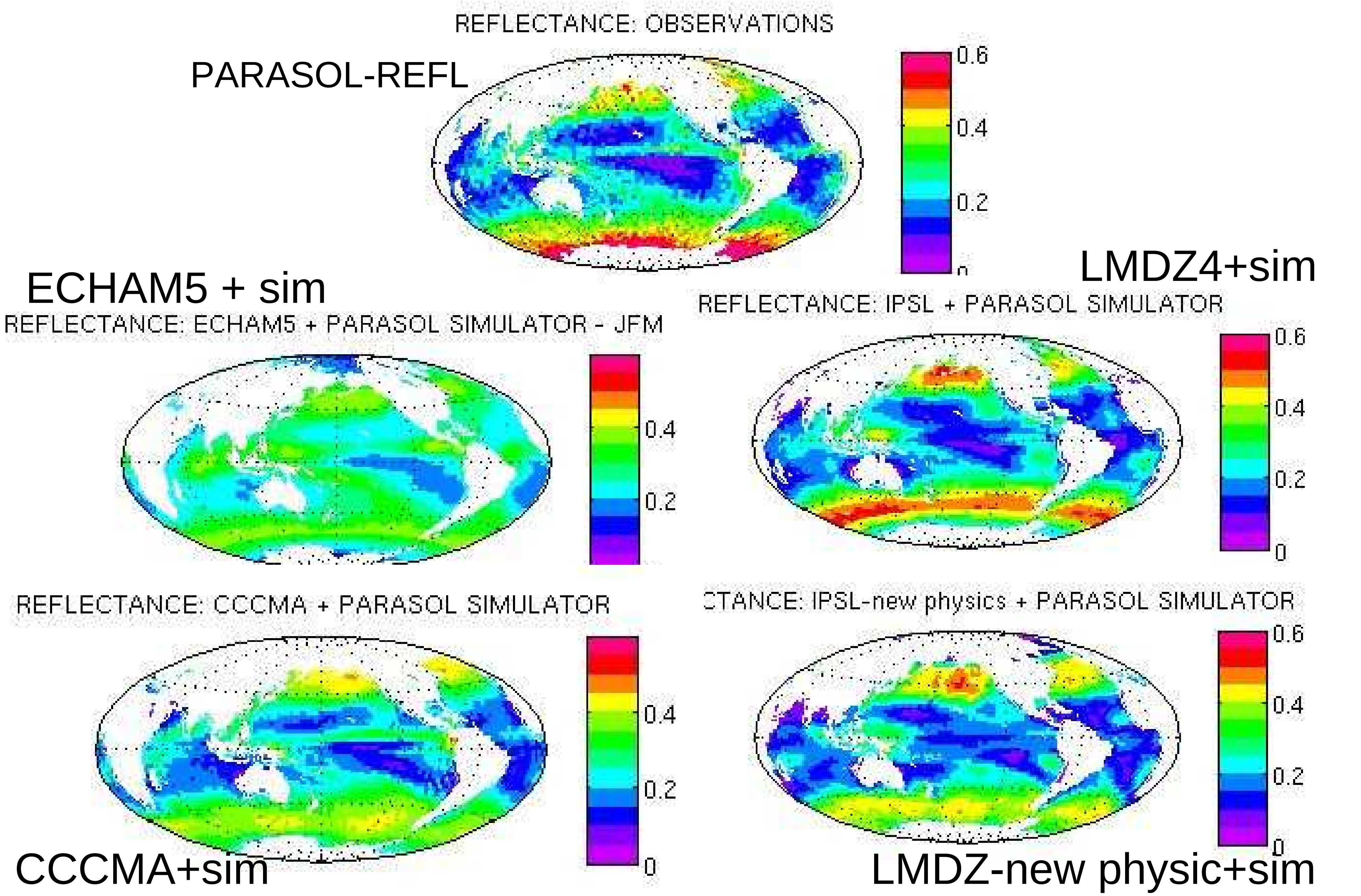
Background (2): Evaluation of Cloud Vertical Distribution



Overestimate:
-High clouds

Underestimate:
- Tropical low clouds
- Congestus
- Mid level mid lat

Background (3): Evaluation of cloud optical thickness



Evaluation of clouds in climate models based on satellite observations

- Generally based on monthly mean TOA fluxes ERBE, ScaRaB, CERES, and ISCCP (e.g. Zhang et al. 2005, Webb et al. 2001, Bony et al. 2004, ….)

- More recently based on monthly/seasonal mean cloud vertical structure and optical depth (e.g. previous slides) using A-train observations and COSP…. CFMIP-2.

BUT , NOT SUFFICIENT because :

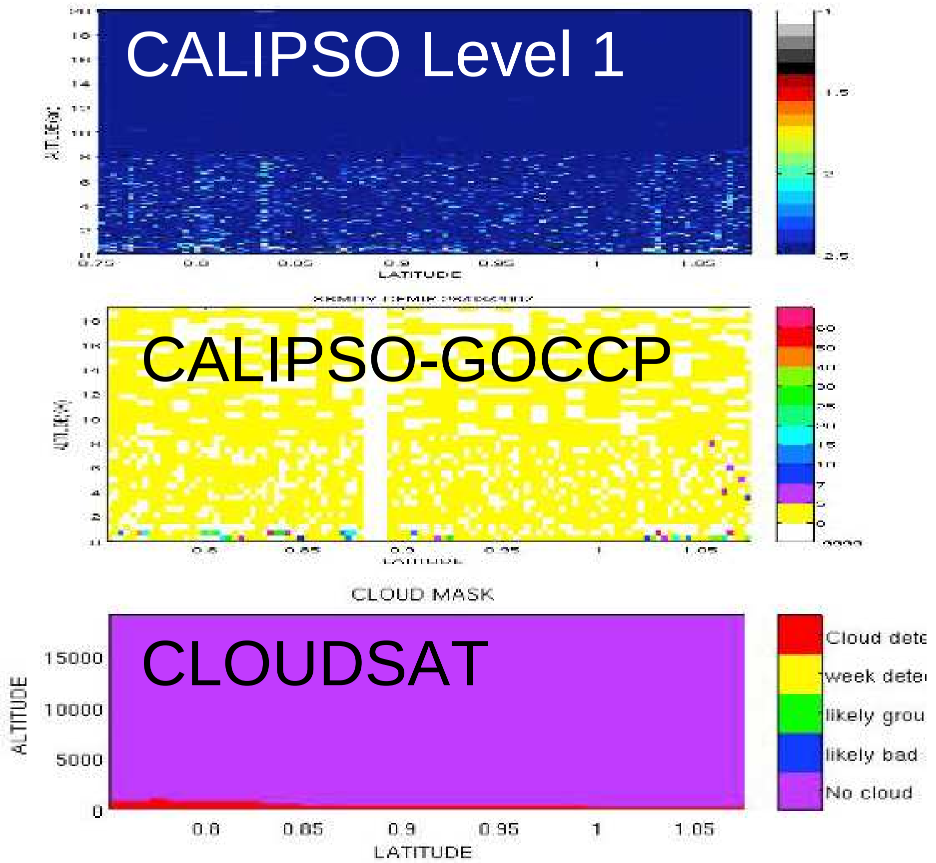
- Errors compensations
- The response of clouds to external forcing depends on the cloud description at the subgrid/instantaneous scale, (not at the seasonal/monthly global scale).
- The physical cloud processes at the subgrid/instantaneous scale are described by parameterizations which need to be assessed directly (not indirectly)

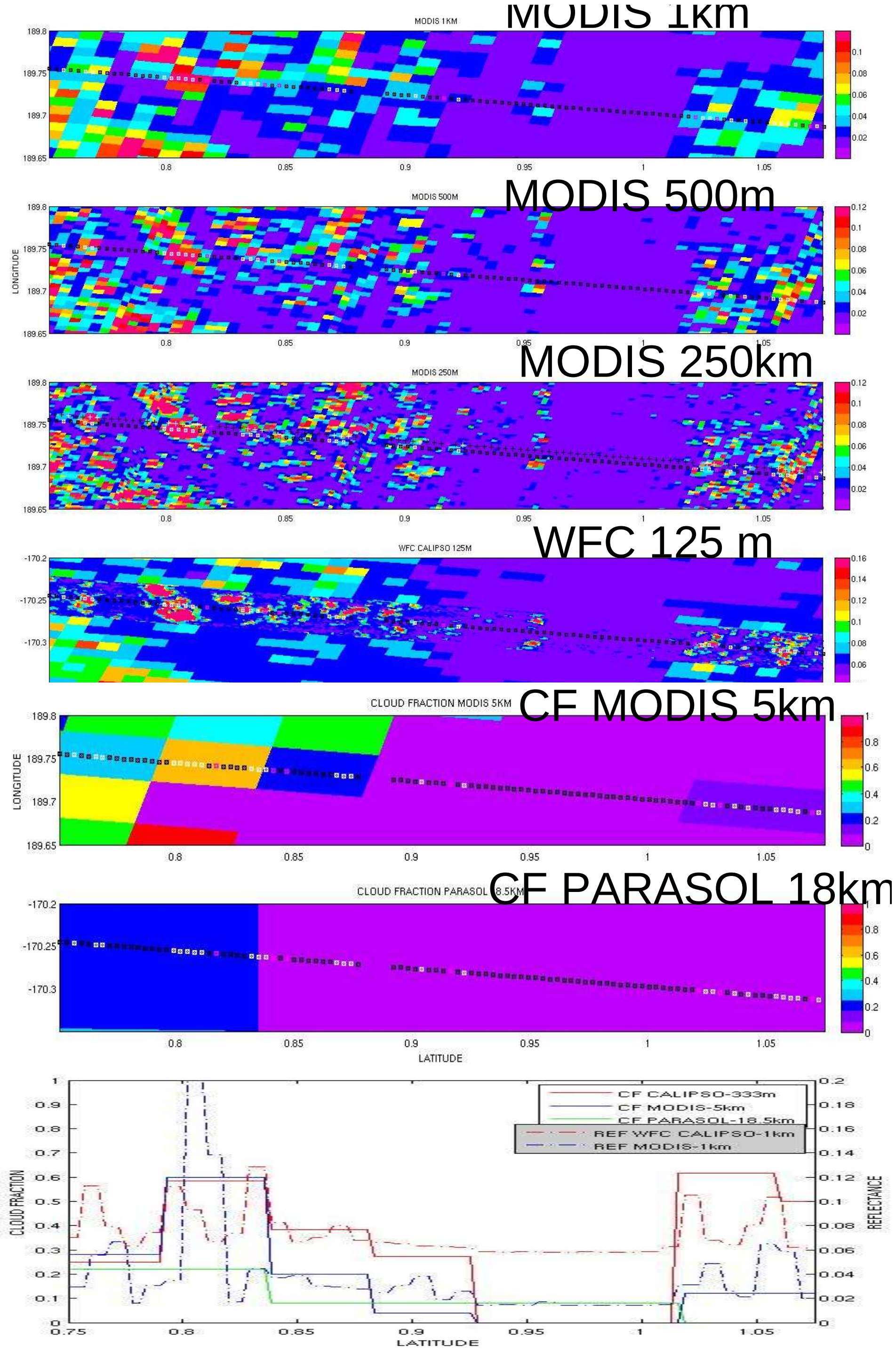
The A-train observations (at high spatial and temporal resolution), do potentially content valuable information to evaluate directly the cloud parameterizations.

⇒ **Talk's goal:**

built valuable observational diagnostics from A-train data at high resolution to evaluate the cloud parameterizations in climate models

A case study: a boundary layer tropical cloud

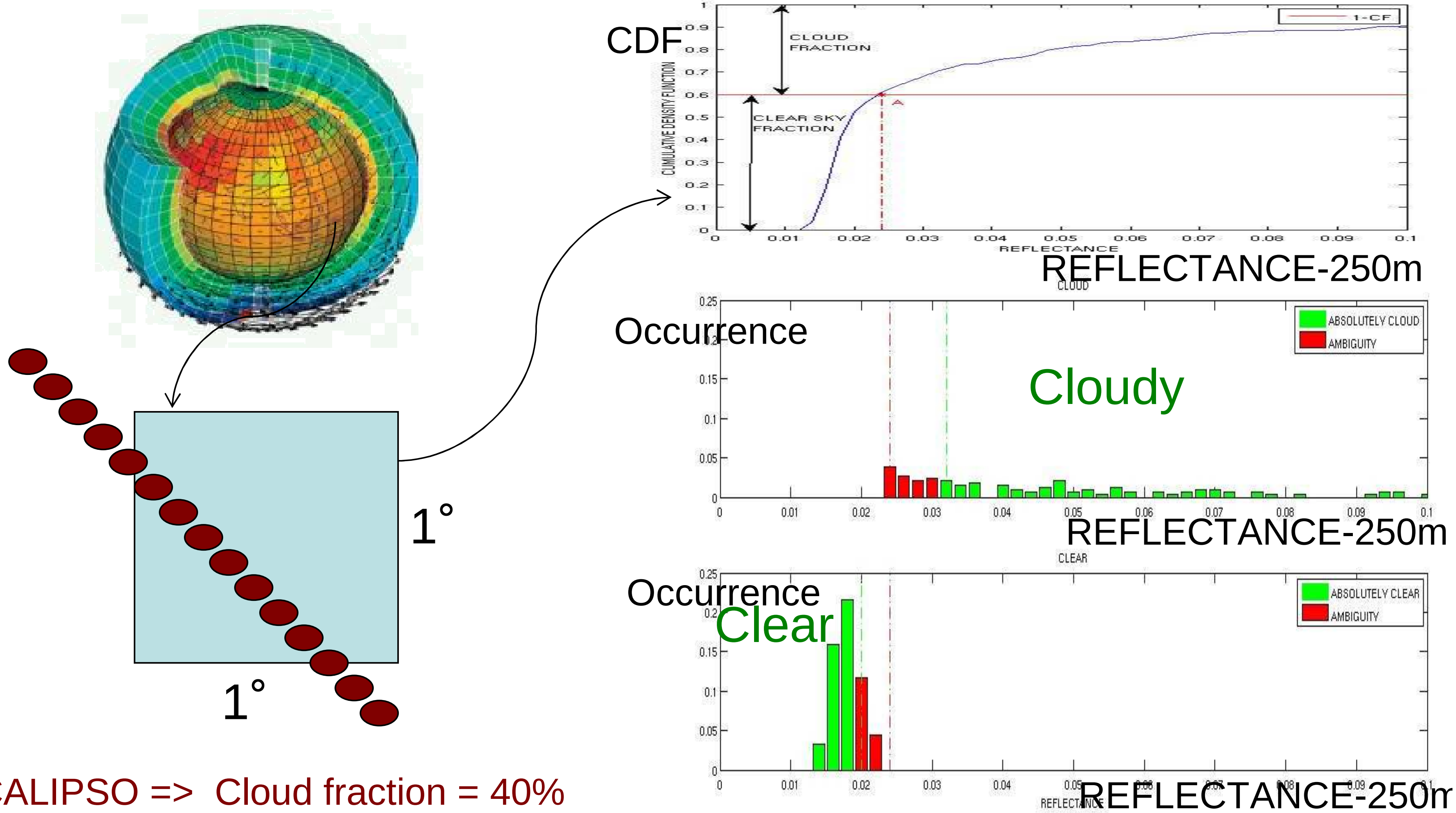




Need a clean separation clear/cloudy
Need colocated and simultaneous observations

CALIPSO :Cloud detection and vertical structure
Colocated Reflectance MODIS250m : Cloud optica

A methodology: from the case study to global statistics using high spatial resolution data



CALIPSO => Cloud fraction = 40%
Clear fraction = 60%

MODIS-colocated => Cloudy Refl,Clear Refl

⇒In each grid box: Daily, Cloud Fraction and Cloudy Refl

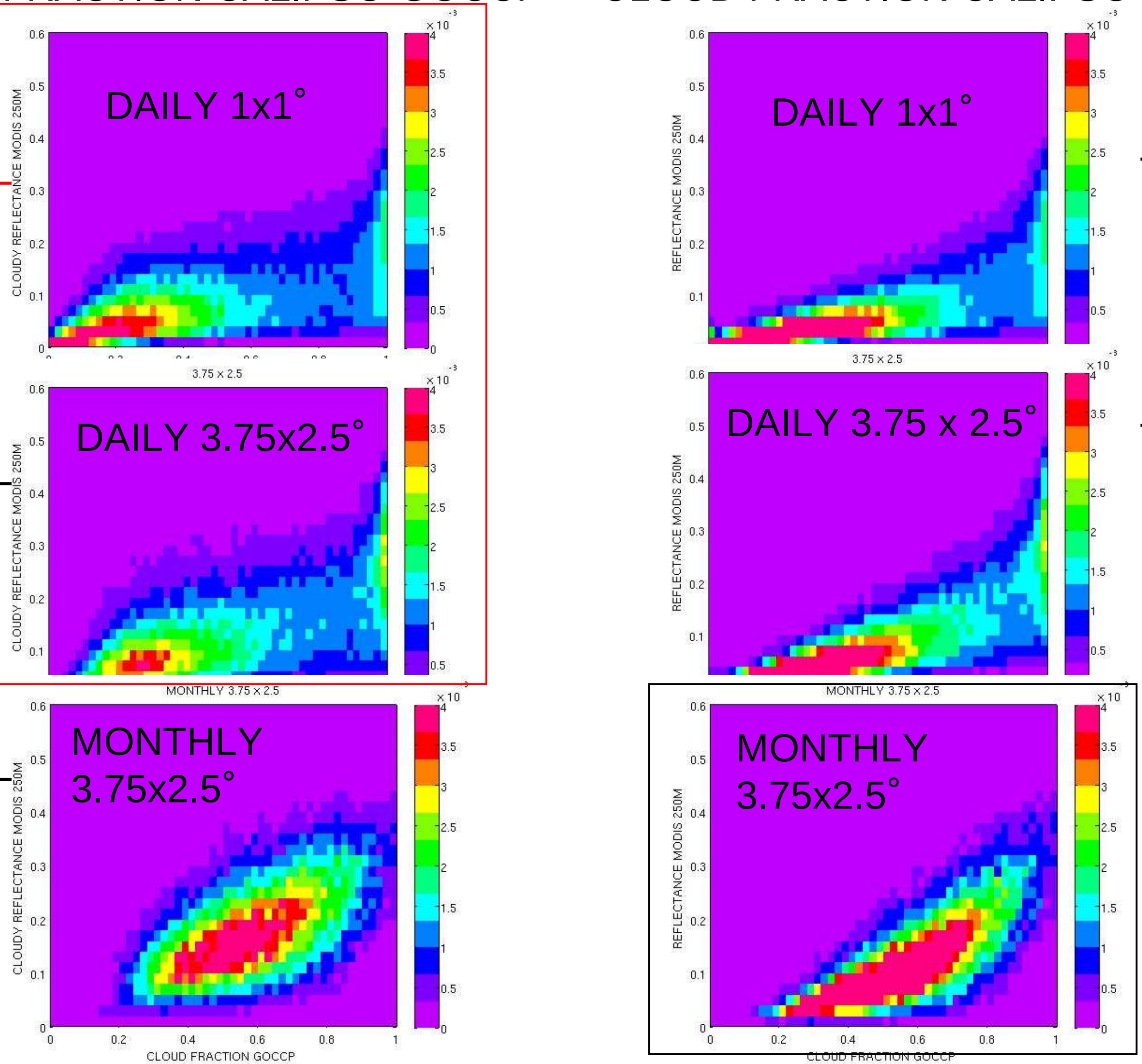
Relation between the cloud optical depth and the cloud fraction - in the observations

CLOUD FRACTION CALIPSO-GOCCP CLOUD FRACTION CALIPSO-GOCCP

CLOUDY-REFL MODIS

CLOUDY-REFL MODIS

CLOUDY-REFL MODIS



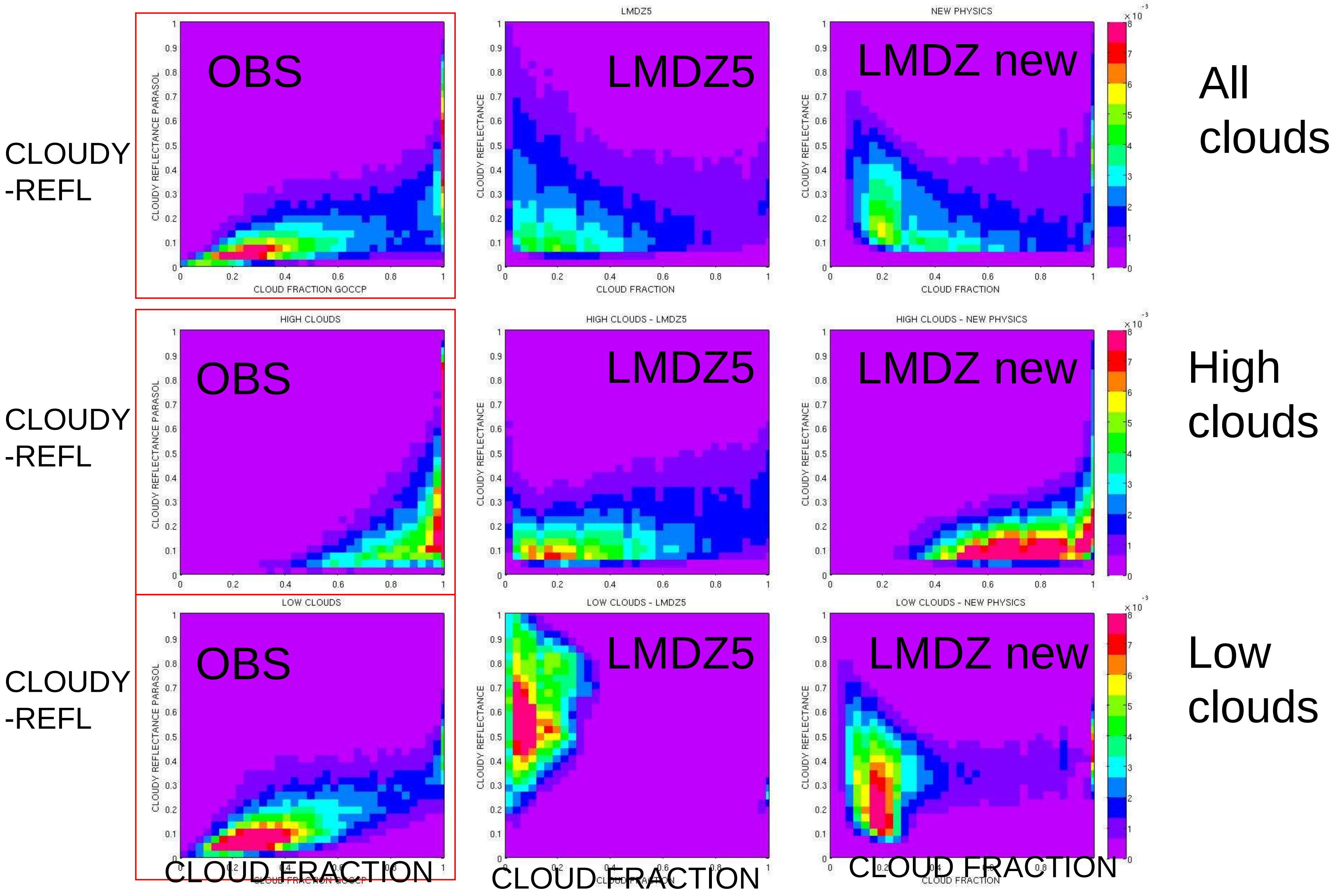
TOTAL-REFL MODIS

TOTAL-REFL MODIS

TOTAL-REFL MODIS

=> Here after, we use « High Resolution » : Cloudy Refl, Daily

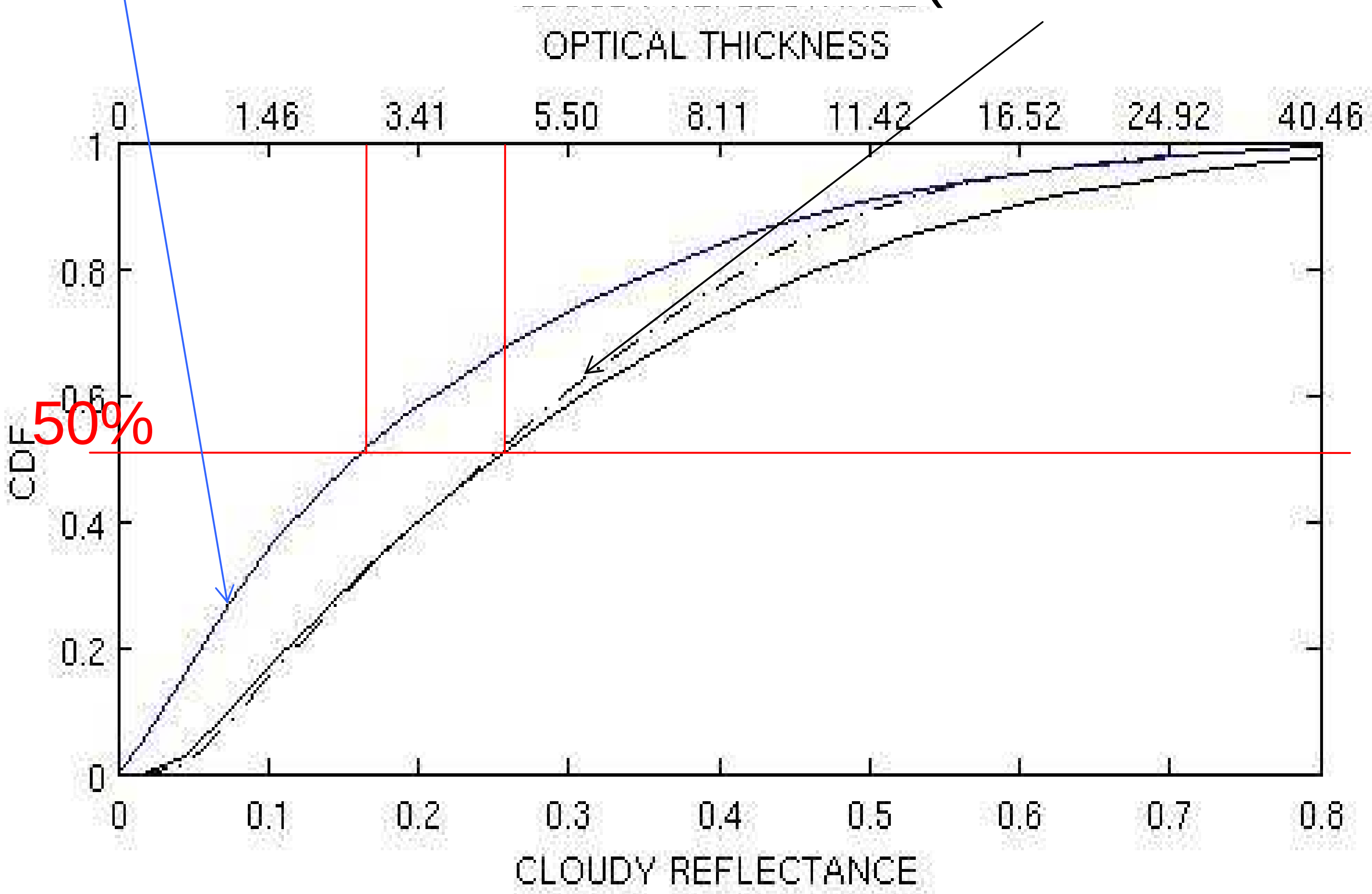
Relation between the cloud optical depth and the cloud fraction– evaluation of the models at high resolution



Cloud optical depth
- Evaluation of models at high resolution

Observations: cloudy-reflectance

GCM+simulateur
(LMDZ5 and LMDZ new physic)



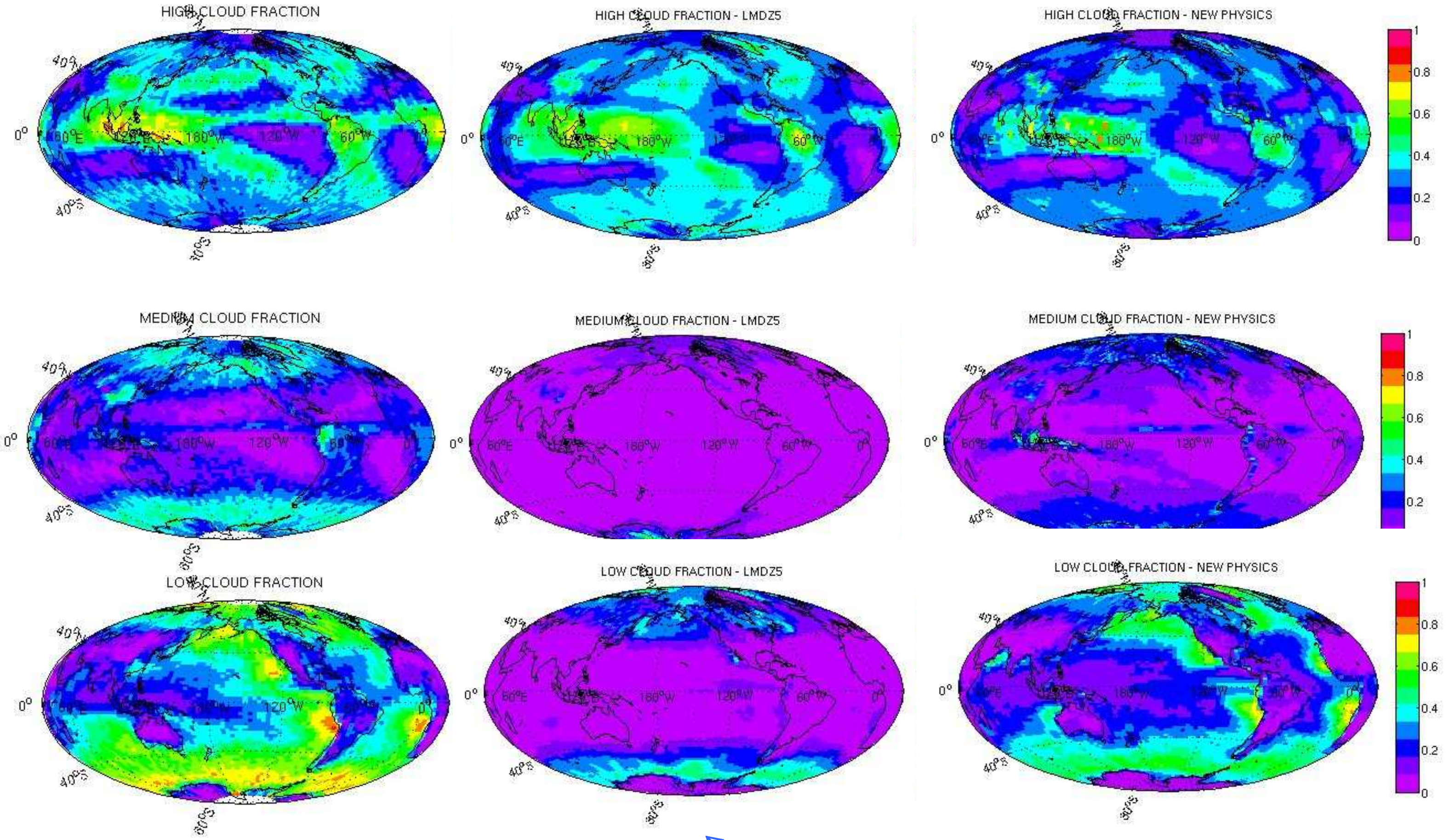
50% of the cloud : Obs optical depth = 2.6
Models cloud optical depth = 4.8

Cloud vertical structure
- evaluation of the models in monthly mean

OBS
CALIPSO-GOCCP

LMDZ5 + SIM

LMDZ new physic + SIM



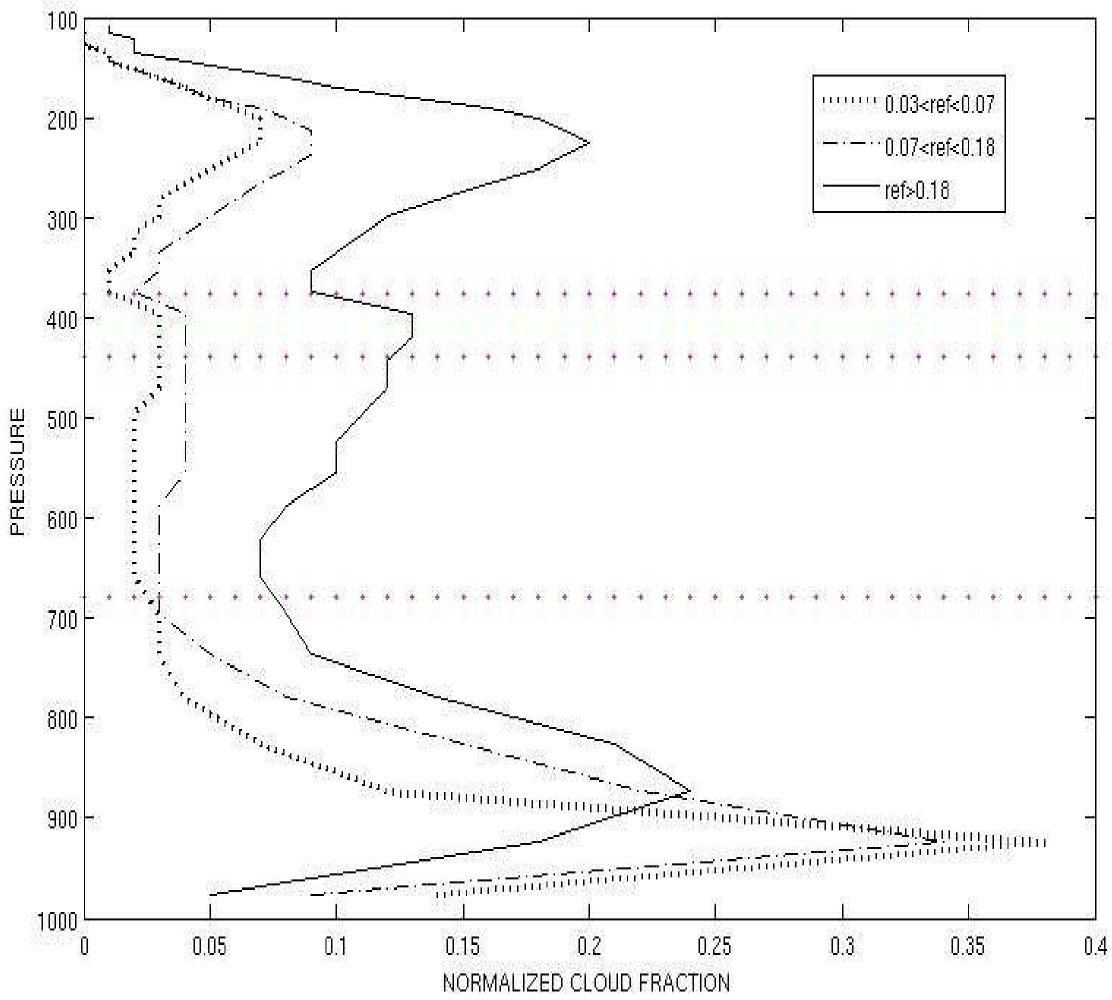
HIGH

MID

LOW

Cloud vertical structure
- observations at high resolution

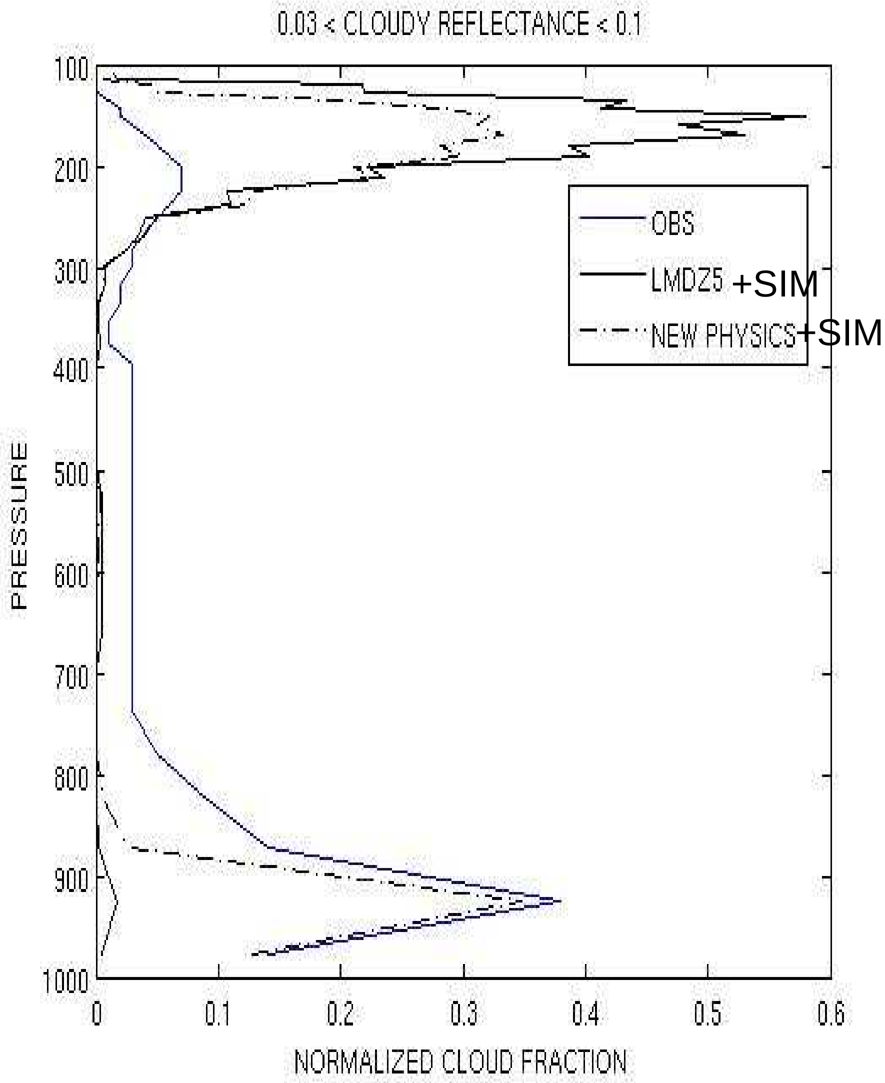
PRESSURE



CLOUD FRACTION CALIPSO-GOCCP

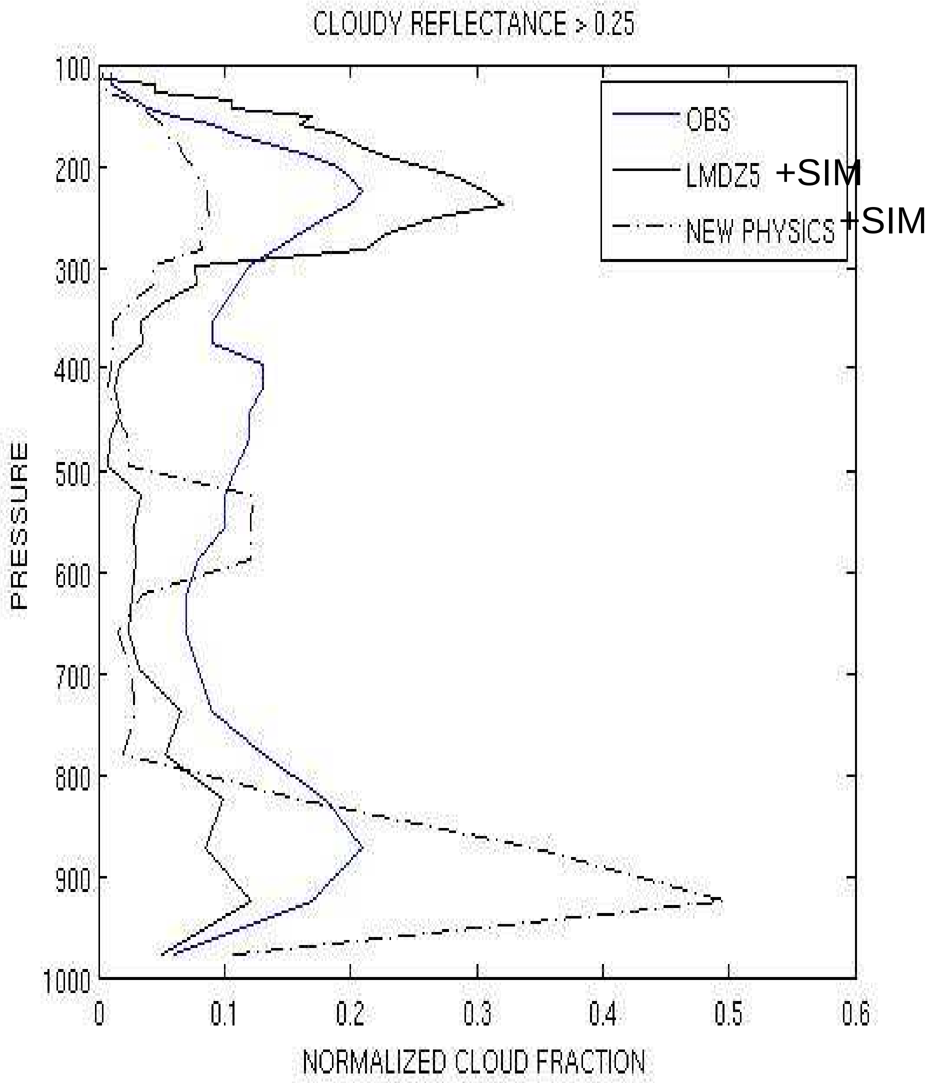
Cloud vertical structure- evaluation of the models using observations at high resolution

OPTICALLY THIN CLOUDS



CLOUD FRACTION CALIPSO-GOCCP

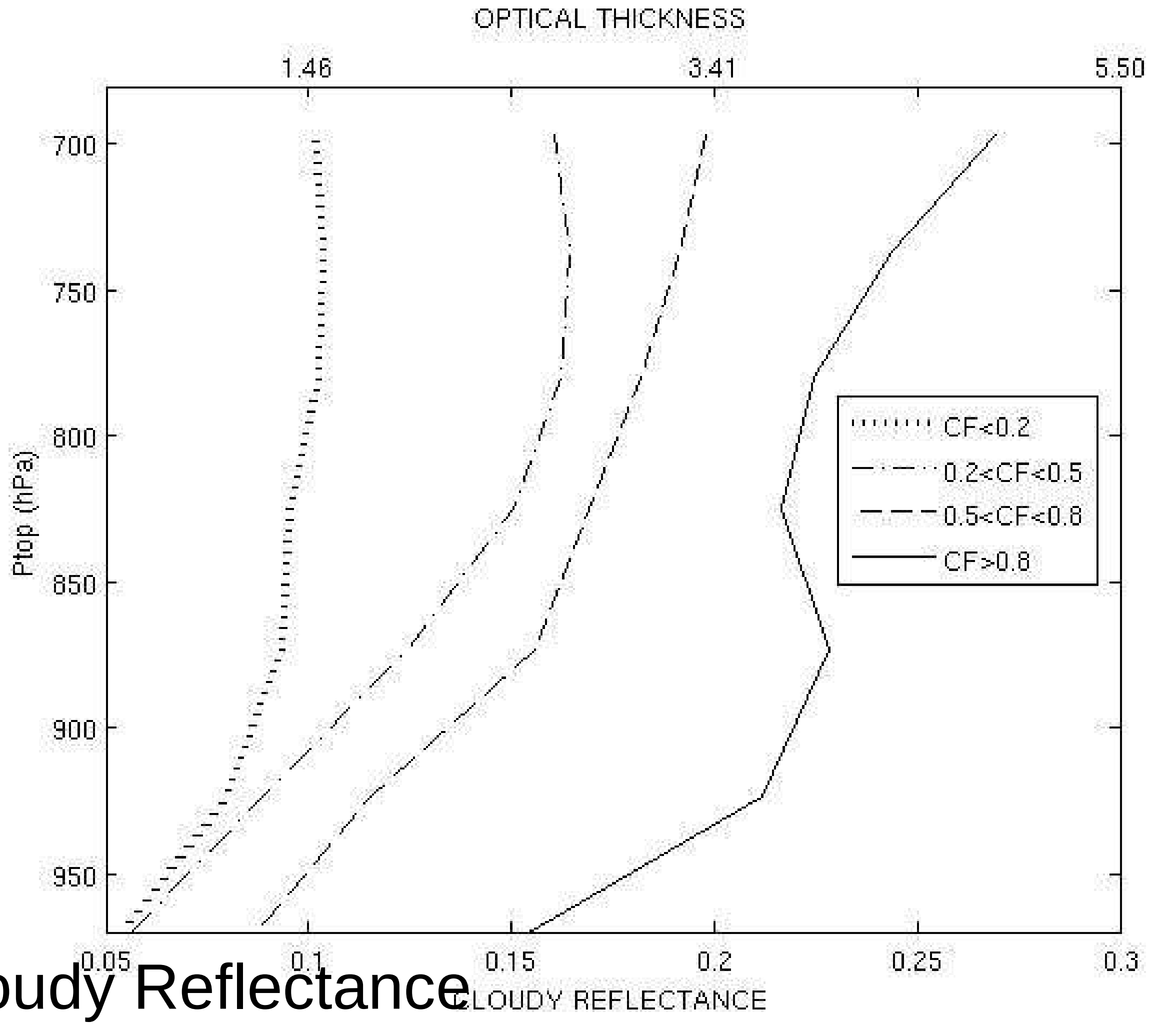
OPTICALLY THICK CLOUDS



CLOUD FRACTION CALIPSO-GOCCP

Focus on Low level tropical clouds – observations at high resolution

Cloud top level

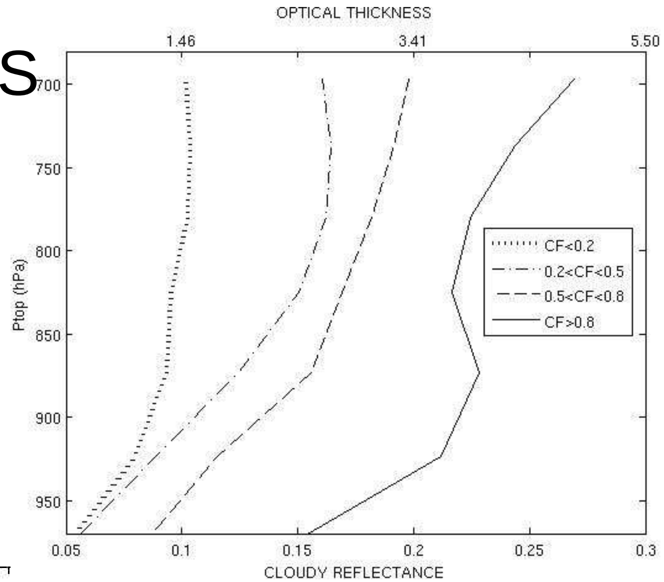


Cloudy Reflectance

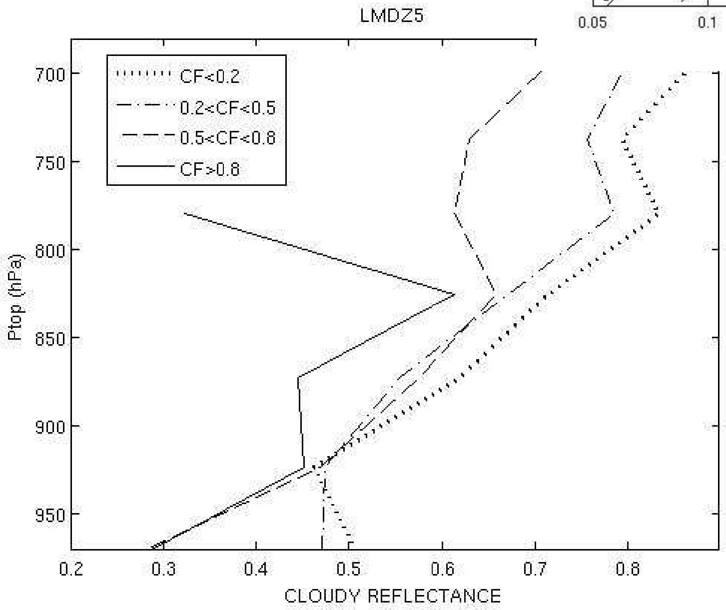
In boundary layer tropical clouds: relation between the Cloud Top Level, the Cloud Fraction, the Cloud Optical Depth

Focus on Low level tropical clouds – evaluation of the model using high resolution observations

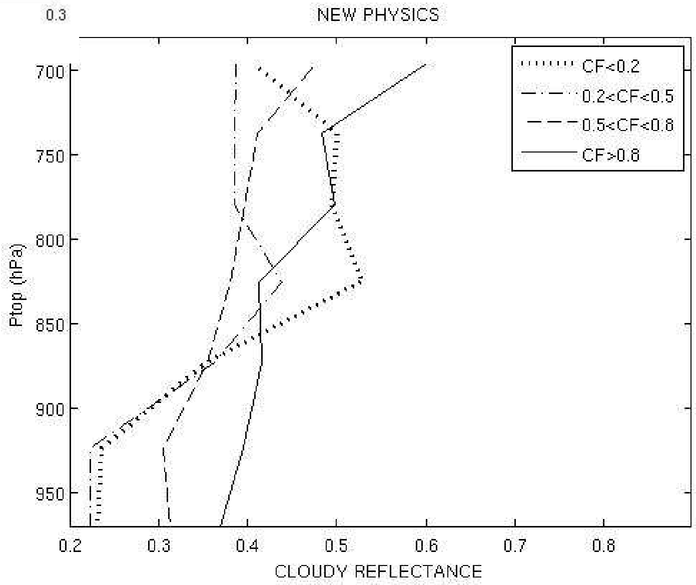
OBS



LMDZ5 + SIM



LMD New Physic + SIM



an example of parameterization assessment …

Conclusion

- A-train observations at « high resolution » is a powerful tool to evaluate cloud description in climate models.
- The spatial resolution (total .vs. Cloud reflectance) and the time resolution (da .vs. monthly) used inthe analysis are critical
- Both versions of LMDz show significant bias in the cloud optical depth, the vertical structure, and the relation between CF and the cloud reflectance
- Analyse of « high resolution » Atrain observations in dynamical regimes to evaluate climate models (not shown)

- <u>Perspective:</u>

  Similar analysis based on« high resolution » Atrain observations to evaluate others climate models

  Evaluation of the cloud thermodynamical phase in climate models

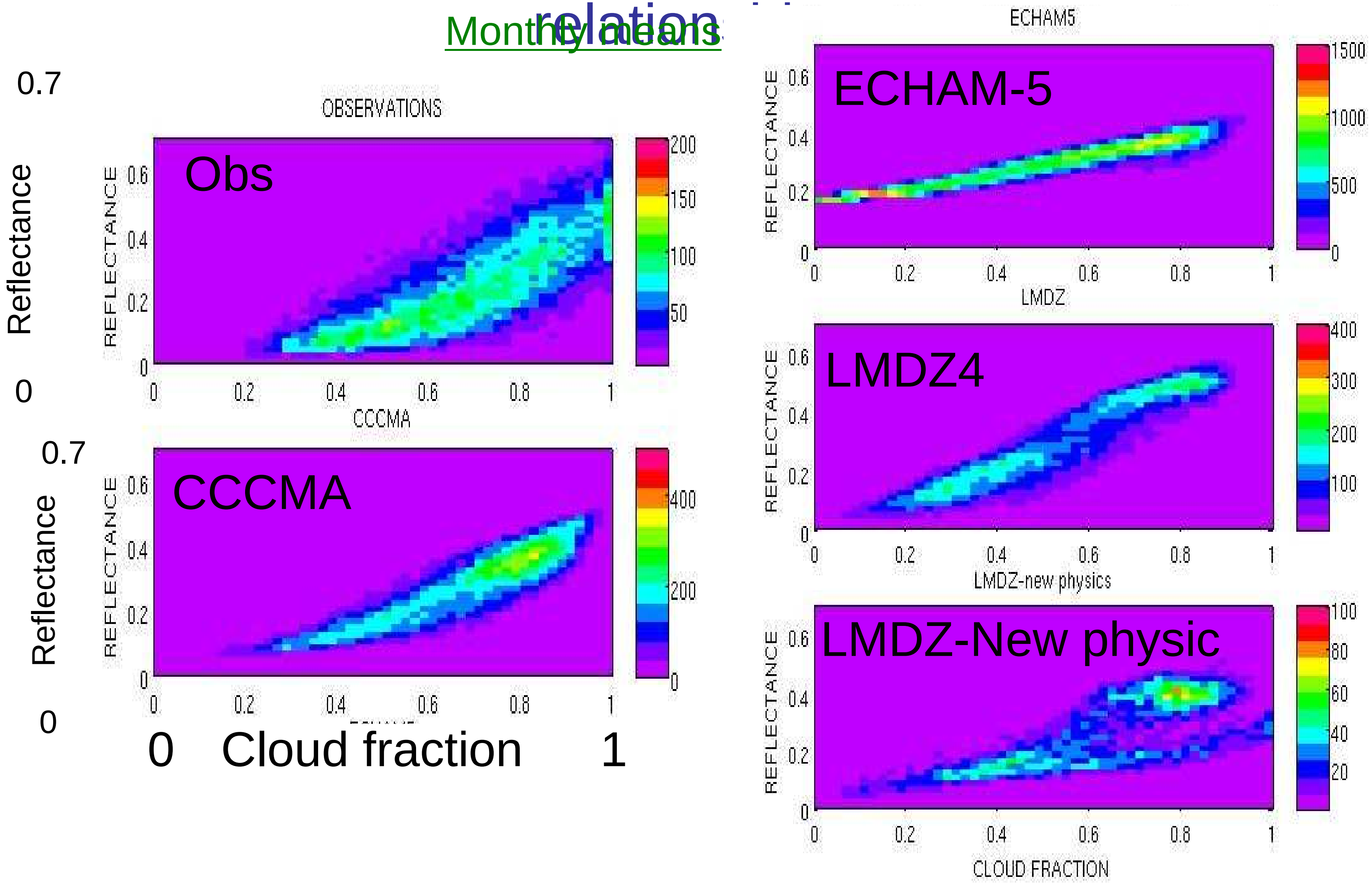
  Evaluation of the new convection scheme in LMDz using « high resolution » Atrain observations

  Coupling CAIPSO-GOCCP with CloudSat for climate model evaluation

The end

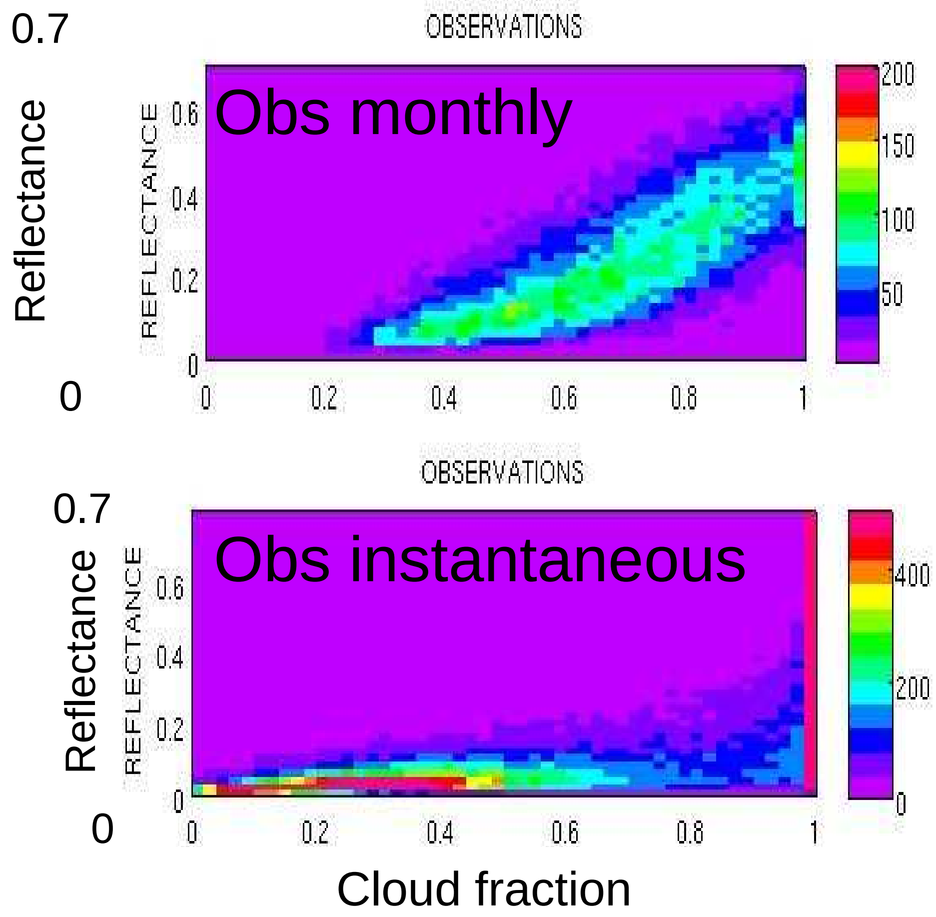
(d1+d3) Cloud cover / cloud optical thickness relation

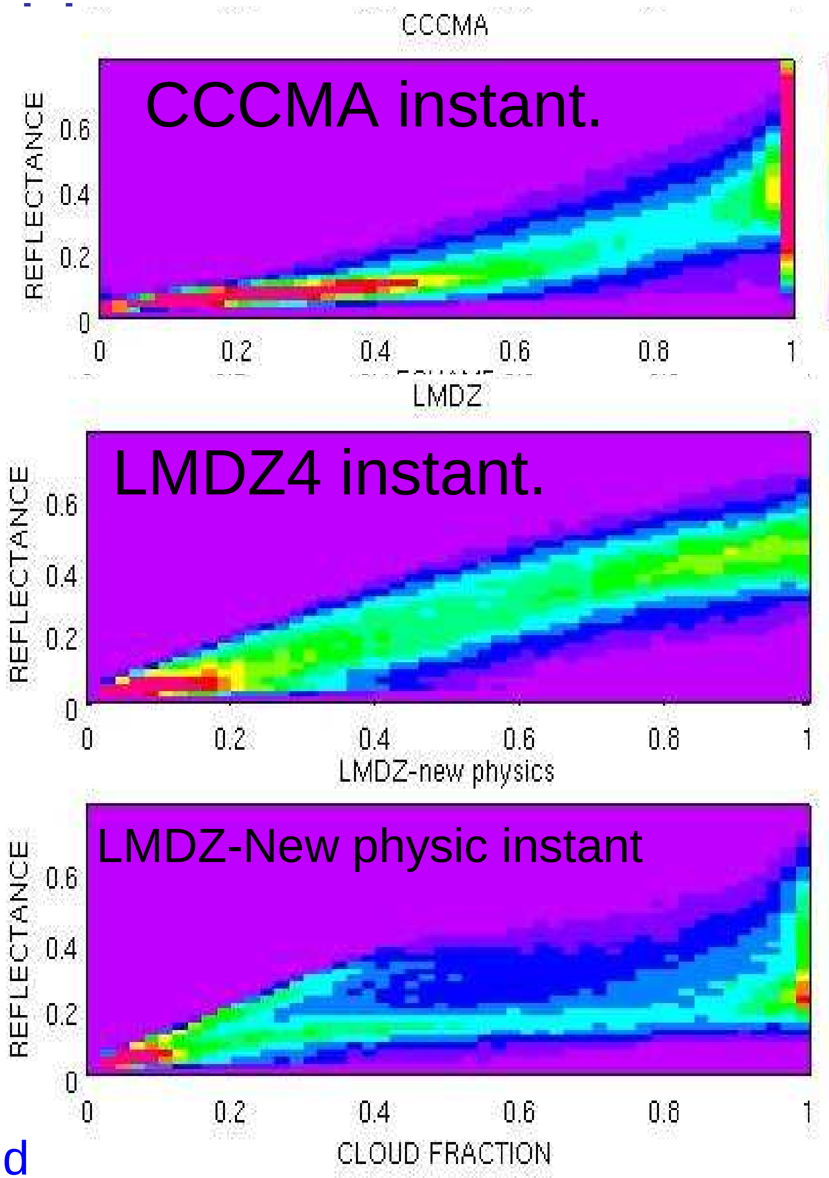
Monthly means



Models reproduce roughly the relationship between the reflectance and the cloud fraction in monthly mean

(d1+d3) Cloud cover / cloud optical thickness relations

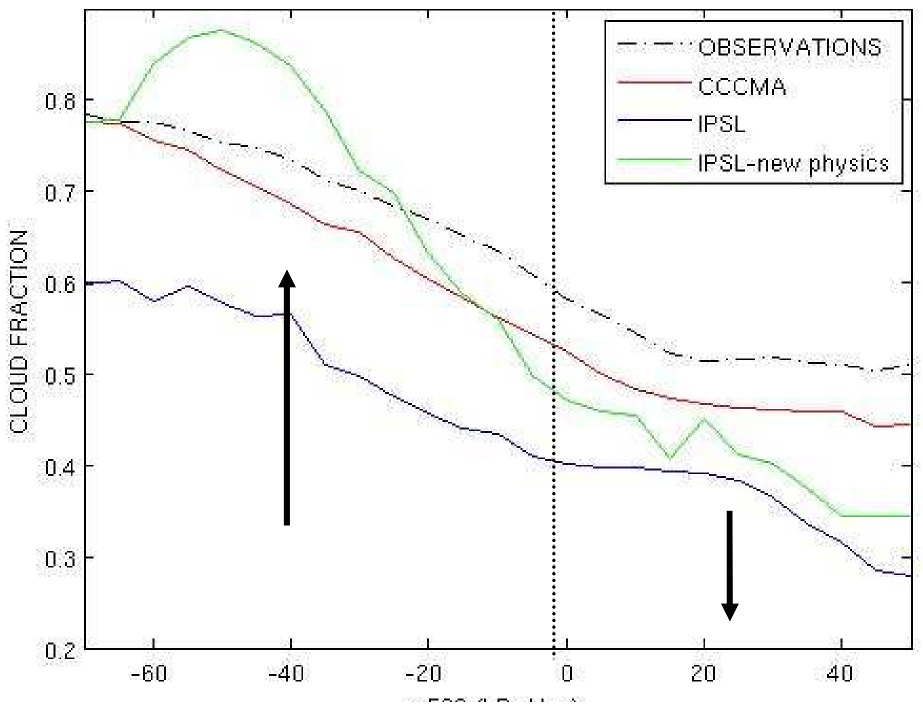




Models have difficulties to reproduce the « instantaneous » relationship between tau and the cloud fraction … needed for cloud feedbacks

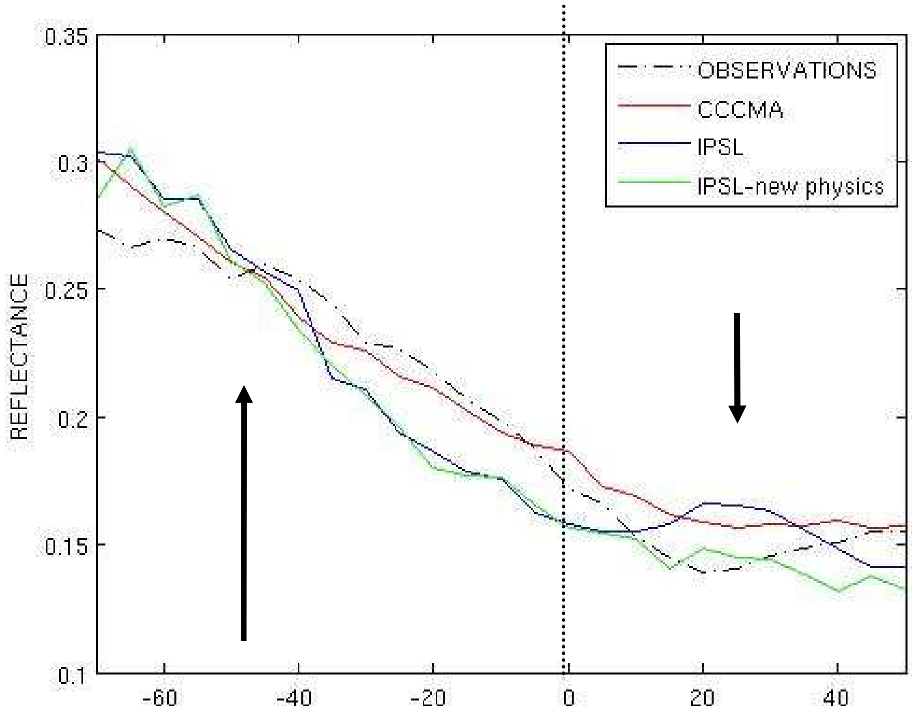
Focus on Tropics
(d1) Cloud cover and (d3) Optical thickness in dynamical regimes

(d1) CLOUD COVER



w500 (hPa/day)
Vertical wind speed et 500hPa

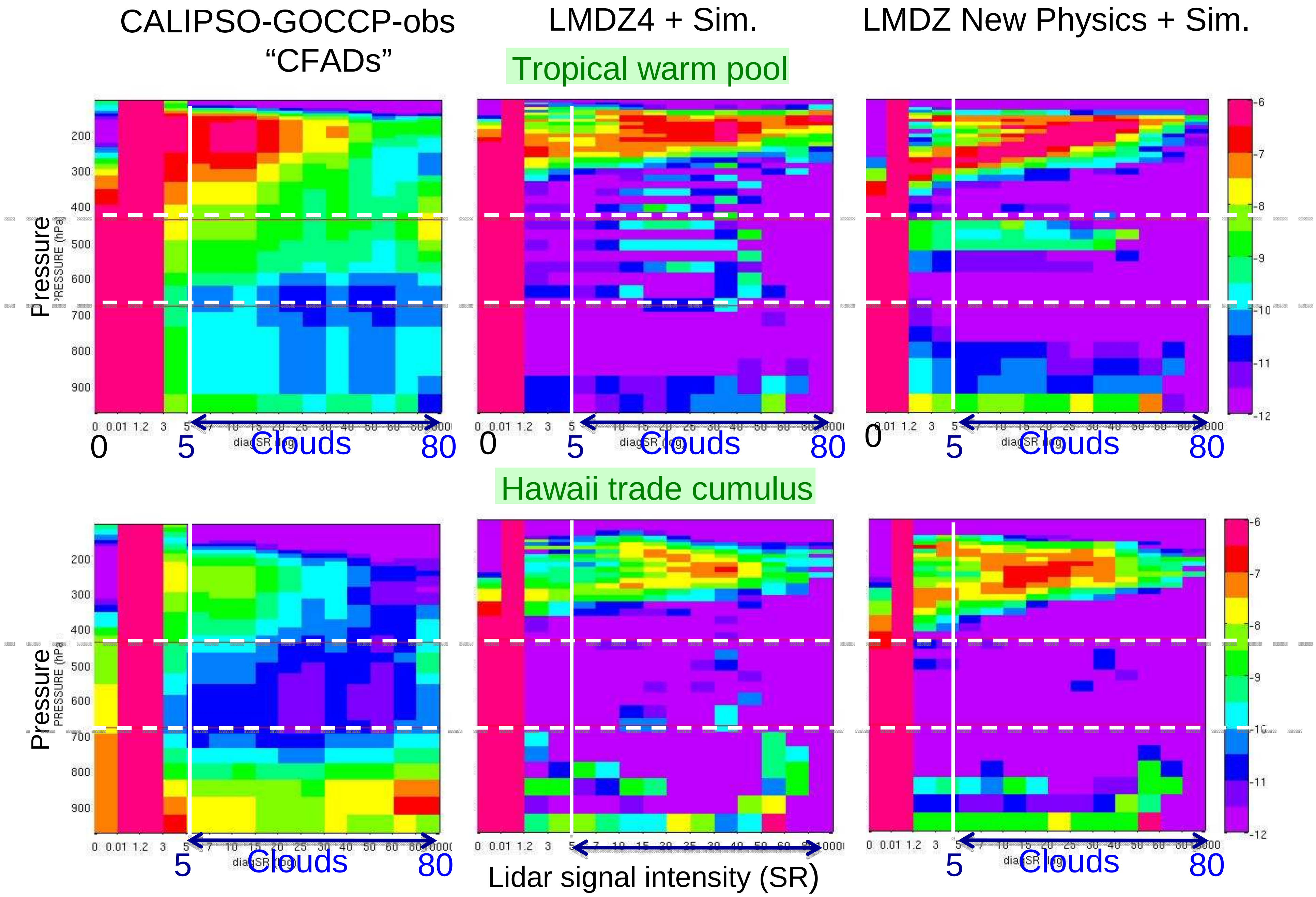
(d4) REFLECTANCE



w500 (hPa/day)
Vertical wind speed et 500hPa

Error compensations between Cloud cover and Optical depth

(d4) Cloud types : focus on Tropics



Conclusions

CALIPSO and PARASOL obs. can help identifying GCM error compensations:

1) between vertically integrated Cloud Cover and Optical Thickness
2) between time scales: instantaneous vs monthly mean
3) in cloud vertical distribution

All the models :

- overestimates high cloud amount
- underestimate total cloud amount
- underestimate tropical low level oceanic cloud amount in subsidence regions

All models exhibit error compensations

None of the models can reproduce the « Cloud Types », characterized by lidar intensity, e.g. the 2 modes of low level clouds and the congestus clouds

Physical interpretations of model/obs differences and inter-model differences … just starts now

CALIPSO and PARASOL simulators are included in COSP:

Chepfer H., S. Bony, D. Winker, M. Chiriaco, J-L. Dufresne, G. Sèze, 2008: Use of CALIPSO lidar observations to evaluate the cloudiness simulated by a climate model, Geophys. Res. Let., 35, L15704, doi:10.1029/2008GL034207.

Simulators: http://www.cfmip.net

"CFMIP Observation Simulator Package": ISCCP, CloudSat, CALIPSO/PARASOL, MISR
(UKMO, LLNL, LMD/IPSL, CSU, UW)

CALIPSO- GOCCP « GCM Oriented CALIPSO Cloud Product » :

Chepfer H., S. Bony, D. Winker, G. Cesana, JL. Dufresne, P. Minnis, C. J. Stubenrauch, S. Zeng, 2009: The GCM Oriented Calipso Cloud Product (CALIPSO-GOCCP), J. Geophys. Res., under revision.

Observations: http://climserv.ipsl.polytechnique.fr/cfmip-obs.html

CALIPSO-GOCCP, PARASOL-REFL, CLOUDSAT-CFAD, CERES-EBAF, …
(LMD/IPSL, UW, LOA, NASA/LarC, …)

This preliminary pilot inter-comparison will be extended to others climate models :

- CFMIP-2 experiment comparison with actual observations
- WGCM/CMIP-5 experiment (*Taylor et al. 2009*) – inter-models comparisons via simulators (doubling CO2, long term)

Today, about 20 models use COSP (CFMIP Obs. Simulator Package)-

fin